AD-A067 401 HONEYWELL INC WEST COVINA CA DEFENSE ELECTRONIC DIV F/G 5/9
USE OF PERFORMANCE MEASUREMENT DATA FROM THE 14A2 ASW TEAM TRAI--ETC(U)
MAR 79 J D BELL, E J PICKERING N00123-77-C-1416
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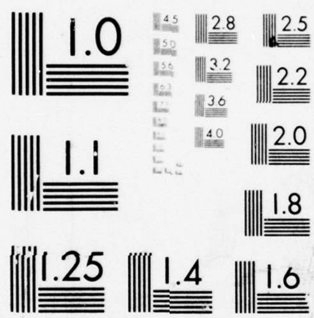
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NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER, SAN DIEGO, CALIFORNIA 92152

NPRDC TR 79-15 MARCH 1979

USE OF PERFORMANCE MEASUREMENT DATA FROM THE 14A2 ASW TEAM TRAINER COMPLEX IN A PERFORMANCE PROFICIENCY ASSESSMENT SYSTEM

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(12)

NPRDC TR 79-15

March 1979

USE OF PERFORMANCE MEASUREMENT DATA FROM THE 14A2 ASW TEAM TRAINER COMPLEX IN A PERFORMANCE PROFICIENCY ASSESSMENT SYSTEM

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

19

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

18 NPRDC TR-79-15

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

9

4. TITLE (and Subtitle)

6 USE OF PERFORMANCE MEASUREMENT DATA FROM THE 14A2 ASW TEAM TRAINER COMPLEX IN A PERFORMANCE PROFICIENCY ASSESSMENT SYSTEM.

5. TYPE OF REPORT & PERIOD COVERED

Final Rep[redacted]t.
Sep[redacted]77 - Sep[redacted]78,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

10 James D. Bell (Honeywell)
Edward J. Pickering (NPRDC)

8. CONTRACT OR GRANT NUMBER(s)

15 N00123-77-C-1416 new

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Honeywell, Defense Electronic Division
West Covina, CA 91790

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

63720N
16 Z0108.PN 31

11. CONTROLLING OFFICE NAME AND ADDRESS

Navy Personnel Research and Development Center
San Diego, CA 92152

12. REPORT DATE

11 Mar[redacted]79

13. NUMBER OF PAGES

63

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 65p.

15. SECURITY CLASS. (of this report)

UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17 Z0108PN31

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Performance measurement
Team trainers
Fleet proficiency
Anti-submarine warfare

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A project is underway to investigate the feasibility of a Performance Proficiency Assessment System that would provide decision makers with information concerning the degree to which Fleet personnel are capable of performing the critical aspects of their jobs. The objectives of this study were to (1) identify surface sonar technician performance measures obtainable from the 14A2 ASW team trainer complex that might provide data useful to Navy personnel managers, (2) identify procedures for obtaining such data during

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training exercises, (3) develop appropriate procedures for data analysis and summarization, and (4) evaluate methods of automating the collection of the required information.

Appropriate performance measures were selected for investigation and computer data collection programs were developed. Data were collected and analyzed from six ASW teams on three separate exercises per team.

The following conclusions were reached: (1) Data from the 14A2 complex can provide inputs to an assessment system: (2) procedures can be developed for collecting and summarizing proficiency/deficiency data so that they can be readily understood by personnel managers; (3) procedures can be developed for automating the collection and analysis of the desired information. Experiments will be conducted to determine the degree to which the types of information described in this report would be useful as part of a Performance Proficiency Assessment System.

FOREWORD

This advanced development effort was conducted in support of Project Z0108-PN, Education and Training, under the sponsorship of the Chief of Naval Operations (OP-099). This is the first in a series of reports relating to subproject Z0108-PN31, Performance Proficiency Assessment System. The work described in this report was conducted to (1) identify quantitative measures of Surface Sonar Technician (STG) performance that can be obtained during Fleet anti-submarine warfare (ASW) team training exercises, and (2) provide an assessment of procedures for using these data in the proposed Performance Proficiency Assessment System.

Appreciation is expressed to Mr. B. W. Yaeger, Senior Principal Human Factors Engineer, Honeywell, who was a co-developer of the basic experimental design for this study. Appreciation is also expressed to Mr. P. V. Asa-Dorian, LCDR R. Johnston, LT R. Van Dyke, and the ASW training instructors of FLEASWTRACENPAC, San Diego, for their extensive cooperation and assistance in data collection.

The technical contract monitor was Mr. Edward J. Pickering.

DONALD F. PARKER
Commanding Officer

SUMMARY

Problem

In order to ensure Fleet readiness, the U.S. Navy is continually seeking new approaches for assessing the job performance of its personnel. While many partial performance measurement systems exist, the Navy does not now have a comprehensive system for the measurement of job performance proficiency. Several shortcomings in performance measurement efforts have been noted (Pickering & Anderson, 1977). A comprehensive and cost-effective system is needed to generate performance measurement data that are readily understood by Navy personnel managers. NAVPERSRANDCEN has proposed a Performance Proficiency Assessment System (PPAS) in response to this need.

Objectives

Previous studies have identified numerous performance measures for ASW team training. The objectives of this study were to (1) identify Surface Sonar Technician (STG) performance measures obtainable from the 14A2 ASW Team Trainer Complex that might provide data useful to Navy personnel managers; (2) identify procedures for obtaining the desired data during team trainer exercises; (3) develop appropriate procedures for analyzing, summarizing, and presenting the data; and (4) evaluate methods of implementing an automated data collection system for the 14A2 Complex that could be used in a more comprehensive PPAS.

Approach

A review of ASW-related documentation was conducted, and questionnaires were used to obtain information from ASW instructors. Candidate performance measures were selected for analysis and evaluation. Computer data collection programs were developed to collect the data from the 14A2E ASW Team Trainer and the associated 14E19 Sonar Trainer. Data were collected from six ASW teams on three separate exercises per team. The data from these 18 exercises were analyzed, and each performance measure was evaluated to determine its applicability in a Performance Proficiency Assessment System.

Conclusions

1. Data from the 14A2 Trainer Complex can provide inputs to a Performance Proficiency Assessment System.

2. Procedures can be developed for summarizing and presenting proficiency/deficiency data so that they can be readily understood by Navy personnel managers.

3. Procedures can be developed for automating the collection and analysis of the desired information.

Future Actions

1. Experiments will be carried out to determine the degree to which the types of performance information described in this report would be useful as part of a Performance Proficiency Assessment System.

2. If it is determined that such information is useful, an effort will be made to identify the steps that must be taken to automate the collection and analysis of performance data from the 14A2 Trainer Complex. Such automation would be based upon the procedures and techniques outlined in this report.

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To convert from	to	Multiply by
yard	meter (m)	.9144
degree (angle)	radians (rad)	.0174
knot (international)	meter per second (m/s)	.5144
second (sidereal)	second (s)	.9922

INTRODUCTION

Problem

Fleet readiness is directly dependent on the Navy's ability to provide trained personnel who are capable of operating its ships, aircraft, and weapons systems. For this reason, the Navy must continually seek new approaches to assessing the degree to which Fleet personnel are trained to perform the critical aspects of their jobs. While many partial performance measurement systems exist, the Navy does not now have a comprehensive system for measuring job performance proficiency. Current procedures fall short for the following reasons:

1. Evaluators often are not trained in performance testing methods.

2. Personnel are usually evaluated by subjective instructor ratings or paper-and-pencil tests.

3. Evaluations tend to be general and do not identify specific deficiencies.

4. Operational requirements take precedence over performance measurement.

5. Frequently, evaluations are compromised for practical or administrative reasons.

A comprehensive, cost-effective system is needed that will provide job performance measurement data that can be readily understood by Navy personnel managers.

Background

The Navy Personnel Research and Development Center (NAVPERSRANDCEN) is investigating the feasibility of developing a Performance Proficiency Assessment System (PPAS). In 1976, a NAVPERSRANDCEN study proposed that a prototype PPAS should be patterned after industrial quality control methods. In this approach, relatively small samples of a product are tested periodically; and when deficiencies are found, appropriate corrective actions are taken (Pickering & Anderson, 1976). A clear distinction was made between the concept of a PPAS and other performance measurement processes under consideration: "Such a system would not be concerned with evaluating individuals or Navy units. It's purpose would be to supply appropriate personnel managers with information on how well their systems are working." Using the guidelines delineated in this study, NAVPERSRANDCEN began an advanced development effort aimed at producing a prototype PPAS for the STG (Surface Sonar Technician) rating.

In 1977, Honeywell's Training and Control Systems Center was funded by NAVPERSRANDCEN to develop performance measurement procedures for the 14A2 ASW Team Trainer.[1] That study was in support of another Center effort that is concerned with developing improved techniques for providing ASW teams with immediate

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[1]The 14A2 Team Trainer is used for refresher training of Fleet ASW teams. Trainers are located at Pearl Harbor, Hawaii; San Diego, California; Charleston, South Carolina; and Norfolk, Virginia.

feedback on their performance.[2] In 1978, Honeywell was funded to expand the scope of their effort to consider how the trainers could be utilized in support of a PPAS for the STG rating. Specifically, the expanded effort evaluated performance measures related to the sonar and underwater battery (UB) plot subteams. This report will describe those aspects of the Honeywell efforts that are pertinent to the development of a prototype PPAS.

Objectives

1. Identify STG performance measures that should provide useful diagnostic deficiency data.

2. Identify STG measurement data available from the 14A2 Complex and the requirements for collecting them.

3. Collect data during selected ASW exercises and use them to evaluate the applicability of potential performance measures in the PPAS.

4. Assess the feasibility of collecting these data operationally.

5. Define appropriate procedures for preparing and presenting the data for use by Navy personnel managers.

6. Evaluate methods of implementing an automated data collection system for the 14A2 Complex that could be used with a more comprehensive PPAS.

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[2]For a full description of that study, see the final report on it (Bell, 1979).

APPROACH

Data Collection

First, questionnaires were administered to 14A2 instructors at the Fleet Anti-Submarine Warfare Training Center, Pacific (FLEASWTRACENPAC), San Diego. The questionnaires were designed to assess the relevance and importance of potential performance measures and to determine the most appropriate techniques for collecting data.

Next, two automated data collection programs and a data reduction program were developed. Data were collected during ASW exercises using the 14A2E Sonar Trainer[3] in independent mode and in joint mode with the 14E19; in independent mode the AN/SQS-23 Sonar was simulated and in joint mode the AN/SQS-26CX Sonar was simulated. Figure 1 provides a flow diagram of the data collection process.

A 14A2 Data Collection Program was developed as a subroutine of the 14A2 Main Trainer Program; it collected data from the XDS-930 Computer on the 14A2 Magnetic Tape Unit (MTU) for all simulated vehicle motion, SQS-23 tracking error, and target motion analysis (TMA). It also recorded problem event data, including the time of events such as weapon assignment, weapon fire, and instructor control settings.

A 14E19 Data Collection Program was developed to provide data on the operation of the 14E19 Trainer when it was run in joint mode with the 14A2E. This program provided sonar tracking data as well as switch or control data for the SQS-26CX Sonar when it was used in place of the SQS-23. Since it was not possible to collect data directly in the 14E19 Trainer, a program was designed to process data from the 14E19 through the Universal Interface Unit for recording on the computer system associated with the 14E23 Trainer, another trainer available at FLEASWTRACENPAC. (A few exercises not originally planned for were recorded using the 14E23 Trainer and simulated SQS-35 Sonar.)

Finally, a separate program provided for data reduction and printout of the recorded data. This program used a computer located in the Honeywell Training and Control Systems Center, West Covina, California.

After the programs were prepared, a data collection plan was devised. Data were to be collected for ASW teams from six ships. Three of the teams were to use the 14A2 in independent mode, and three were to use the 14A2 and 14E19 in joint mode. Data were to be collected on three exercises per team, representing three increasingly difficult levels of training. The training levels were designated by FLEASWTRACENPAC as exercise categories. Category 1 exercises were intended for team familiarization with the training equipment and overall team training objectives; therefore, data were not collected from exercises in this category.

Category 2 exercises involved ownship (O/S) and an assist ship, which together form a search attack unit (SAU); another ship designated as a high value unit (HVU); and a target submarine (TS). The primary objective of the ASW team was to protect the HVU and prosecute the attack against the submarine with rockets (ASROC) and over-the-side (OTS) weapons.

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[3] The 14A2E is one of two 14A2 Sonar Trainers at FLEASWTRACENPAC.

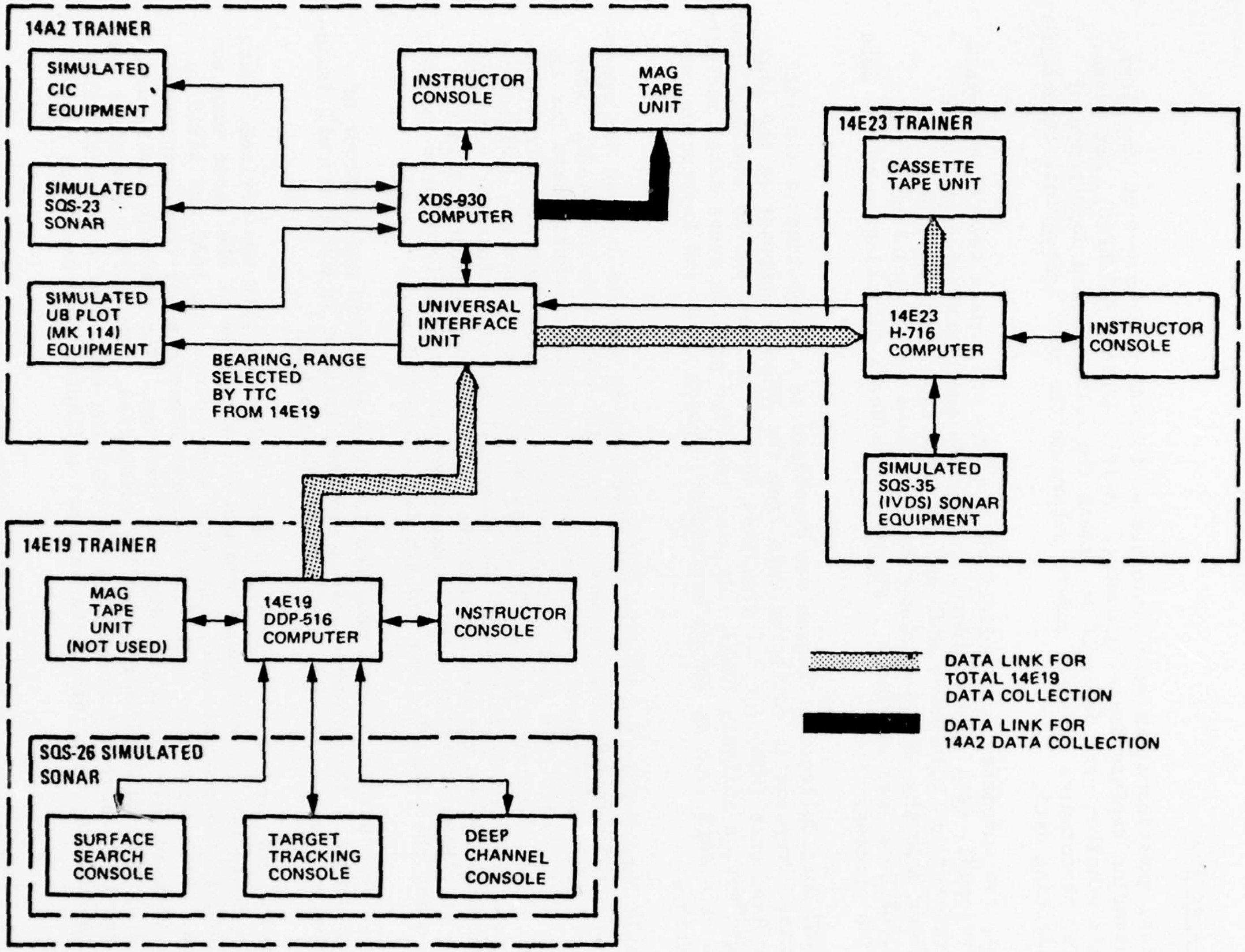

Figure 1. Simplified flow diagram of data collection programs for the 14A2 complex.

Category 3 exercises involved SAU, HVU, TS, and one fixed-wing ASW aircraft (A/C). The primary objective was to protect the HVU and prosecute the attack against the submarine with ASROC, OTS, and A/C vectored attacks (VECTACS).

Category 4 exercises involved O/S with no assist ship, an HVU, TS, and two A/C, one fixed-wing and one ASW helicopter. The primary objectives were the same as for Category 2; however, more complex communications were involved.

The three categories of exercises were differentiated primarily by the combinations of simulated vehicles in the exercise and by the exercise objectives. The difficulty level of each exercise was reflected in more complex communications; however, many operational tasks were not affected by exercise category.

An attempt was made to establish as controlled a study as possible through the following conditions:

1. Personnel manning key team positions were to maintain those positions during the three exercises used for data collection.

2. Instructors were to maintain the same level of target submarine maneuvering complexity and instructor assistance for all six teams within a given exercise category.

3. Instructors were to use checklists specifically developed for this study to maintain communications and procedural error data.

All data were to be collected at FLEASWTRACENPAC during advanced ASW team training (K-2E-1070 course). All data were to be collected on the 14A2E Trainer, either in independent mode or in joint mode with the 14E19 (SQS-26CX Sonar) Trainer.

Data Reduction

The data were analyzed in terms of PPAS requirements. The following questions were considered:

1. What procedures would be effective for summarizing and presenting data effectively to personnel managers?

2. To what degree does measured performance represent real performance?

3. What approaches would maximize the usefulness of information retrievable from team training exercises?

4. What steps must be taken to obtain routinely the desired information from the 14A2 Trainer Complex? Specifically, what hardware and software modifications would be necessary to implement an automated performance measurement system, and what additional display or printout devices would be needed?

Problems Encountered

Due to the heavy training load imposed on FLEASWTRACENPAC, some constraints were necessarily placed on the data collection effort. First, data collection

had to be conducted on a "not to interfere" basis. Second, instructors were able to assist in data collection only to the degree that their training functions were not degraded. Despite these constraints, data collection was accomplished for all exercises. Minor programming and hardware problems were encountered. Consequently, the following deviations from the data collection plan resulted:

1. Data were recorded for six ships as planned. However, equipment configurations differed on some of the ships, and this determined the operational trainer setup used for the ship's ASW team.

2. Problems were experienced with some data printouts, and alternate exercise data were used where it was necessary and appropriate.

3. As the activity level increased, it was not always possible for instructors to record procedural and communications errors.

4. Since emphasis was placed on team training, instructors often dictated sonar or UB plot equipment control settings, which reduced capability to measure procedural errors.

Table 1 shows the equipment configurations for the ships involved and summarizes deviations from the original plan. These deviations did not seriously compromise the data analysis capability, and to some degree they provided further enlightenment as to the problems involved in using ASW team trainers to evaluate the performance of sonar technicians.

Table 1

ASW Teams, Equipment Configuration, and Deviations from Data Collection Plan

Ship	Equip. Configuration	Deviations
A	14A2/14E19 (SQS-26CX Sonar) MK 53 Fire Control	None.
B	14A2/14E19 (SQS-26CX Sonar) MK 53 Fire Control	Data from a more advanced exercise used in place of Exercise Category 3.
C	14A2/14E19 (SQS-26CX Sonar) MK 53 Fire Control	None.
D	14A2 (SQS-23 Sonar) MK 268 Torpedo setting panel No fire control	No fire control data. No sonar accuracy data.
E	14A2/14E23 (SQS-35 Sonar) MK 268 Torpedo setting panel No fire control	Sonar was not SQS-23, but similar. No fire control data. No sonar accuracy data.
F	14A2 (SQS-23 Sonar) MK 38 Fire Control	No Exercise Category 3 data printout. Exercise Category 4 data used for two exercises.

EVALUATION OF POTENTIAL PERFORMANCE MEASURES

All potential sonar and underwater battery (UB) plot subteam performance measures were evaluated. Four categories of measures were included: accuracy, time, communications, and procedures. The basic criteria used to evaluate measures in each category were (1) the probability of obtaining the measure in a team training exercise, and (2) the usefulness of the measure in a PPAS.

Sonar Subteam Measures

The sonar subteam is distinctively different for teams using the SQS-23 Sonar and the SQS-26CX Sonar. The key personnel comprising the SQS-23 Sonar subteam are the console operator and the sonar supervisor. Key personnel for the SQS-26CX Sonar are the B-scan (surface channel) console operator, A-scan (deep channel) console operator, target tracking console (TTC) operator, and sonar supervisor.

Sonar Accuracy Measures

Sonar Range and Bearing Error. Sonar operator range and bearing errors were calculated by comparing the ranges and bearings an operator obtained through manipulation of the tracking console (that is, the observed positions) with the actual ranges and bearings of the contacts. These data were obtained by means of specially developed computer programs. For the SQS-23 Sonar the actual positions were available from the past position table in the 14E19 Main Trainer Program. The actual positions were recorded on computer tape along with the observed positions; the range and bearing errors were calculated by means of a computer program designed for use at the Honeywell Facility in West Covina. For the SQS-26 Sonar, range and bearing errors were computed internally and displayed on the 14E19 instructor's console. Error data were obtained directly by reading the range and bearing output words in the 14E19 Main Trainer Program.

Ideally, range and bearing error should be sampled once every new data time (NDT). NDT is the sonar range and bearing input to the fire control, once sonar is placed in contact and track operation. For the SQS-23 Sonar, NDT is automatic at the end of each sonar ping cycle. For the SQS-26, NDT is manually entered using the tracking console NDT button, but for all practical purposes it is once per sonar ping cycle. For all recorded exercises the sonar range scale was set so that the ping cycle time was 12.5 seconds; consequently, NDT was 12.5 seconds. Due to hardware limitations in this study, data were sampled at 10-second intervals, rather than each NDT. However, on two exercises it was necessary to record the range and bearing data manually, once per NDT, by observing the instructor's console error readouts. A comparison of these two exercises with all other exercises indicated that there was no significant distortion due to the 10-second sampling interval.

For each ship, the arithmetic average ($\overline{X}$), standard deviation (σ), and root mean square (RMS) for sonar range and bearing error were calculated. (See Tables 2 and 3.) The $\overline{X}$ represents a tracking "bias" or average error, while the σ summarizes tracking variance or consistency. The RMS provides a measure showing the combined effects of tracking bias and consistency, where the RMS is related to the $\overline{X}$ and σ as shown in the following equation:

Table 2

Sonar Range Error (yards)

Ship	$\overline{X}$	σ	RMS
	Exercise Category 2		
A	103	46	113
B	98	93	134
C	144	80	164
F	227	273	348
	Exercise Category 3		
A	116	117	163
B	146	58	157
C	70	46	82
	Exercise Category 4		
A	165	98	190
B	90	60	107
C	123	84	148
F	32	66	73
F[a]	67	80	103

[a]For ship F there was no exercise Category 3 data available; therefore, an additional Category 4 exercise was recorded.

Table 3

Sonar Bearing Error (degrees)

Ship	$\overline{X}$	σ	RMS
	Exercise Category 2		
A	2.50	4.43	5.00
B	1.95	1.71	2.57
C	1.24	.76	1.45
F	.44	.64	.76
	Exercise Category 3		
A	1.84	2.39	2.99
B	.73	.44	.84
C	.24	.35	.41
	Exercise Category 4		
A	1.27	1.25	1.74
B	.83	.34	.90
C	.46	.40	.60
F	.10	.81	.81
F[a]	1.10	1.12	1.52

[a]For ship F there was no exercise Category 3 data available; therefore, an additional Category 4 exercise was recorded.

$$RMS = \left[\bar{X}^2 + \frac{n-1}{n} (\sigma)^2 \right]^{1/2}.$$

From this equation it can be seen that RMS increases if either the $\bar{X}$ or σ increases. The RMS is interpreted as an average, as is the $\bar{X}$. The $\bar{X}$ may appear to show accurate tracking where positive and negative (leading and lagging) errors are self-canceling, but the alternating errors, resulting from inconsistency, will be evident in a larger σ and a larger absolute error value (RMS). A comparison between SHIP A and SHIP B on range error for Category 3 (Table 2) illustrates this point.

Several constraints must be taken into account when recording and evaluating sonar tracking error. First, the recording of sonar range and bearing input should commence after an established interval following contact, perhaps two or three ping cycles. Frequently, the first two or three NDT inputs show significantly higher errors because the operator goes from SEARCH to CONTACT before fully positioning his cursor. The delay will ensure that these errors are not recorded. Second, tracking error should not be evaluated during multiple-echo (M/E) situations. Multiple echoes occur when a simulated decoy vehicle is activated on the sonar displays at the same range and bearing as the target submarine. At that time, the sonar and CIC teams are being exercised in multiple-echo procedures (to be explained in a subsequent section) and tracking errors will be abnormally large. Once the operator decides which is the correct target and begins continuous tracking, the decoy is deactivated on the sonar display. At this time, recording of error data should be reinstated provided that contact is maintained. Finally, the automatic recording of tracking error data should be terminated when the sonar is switched to the LISTEN mode, out of CONTACT to LOST CONTACT, or when the submarine is removed from display on sonar by instructor action or ensonification math model constraints.

Range and bearing summary statistics are very descriptive of performance and help pinpoint basic tracking deficiencies within a specific exercise. The instructor or trainee could determine if there is specific tracking bias or inconsistency. However, the measures are probably not the most appropriate to show general tracking accuracy. The tracking bias may be affected by doppler and target aspect. The sonar operator may purposely position the cursor to lead or lag the target in range depending on whether the target is closing or opening in range. It was not possible to fully assess this effect with the limited data base, and it will probably be necessary to develop algorithms to attenuate tracking error bias as a function of doppler rate and target aspect.

Sonar Miss Distance. Sonar miss distance represents the combined effect of sonar range and bearing error. Sonar miss distance can be derived from range and bearing error for each NDT. Obviously, the same constraints and limitations that apply to collecting range and bearing error data apply to sonar miss distance.

Sonar miss distance was calculated manually from sonar data printouts. Means and standard deviations are not appropriate measures of miss distance. The arithmetic mean is an average of a set of data along one axis, in which values of opposite direction are self-canceling. The RMS is an average of the absolute values of the miss distance without respect to direction. It more

accurately reflects real error; consequently, it is a more appropriate measure. However, when the RMS miss distance is presented in terms of total yards from target, comparisons between ships cannot be readily made because miss distance is partially a function of target range. Therefore, in order to make comparisons between ships more meaningful, the RMS total yards miss distances were corrected for range differences by calculating the RMS miss distance per 1000 yards of range (RMS in mils) as shown by the following formula:

$$\text{RMS miss distance per 1000 yards} = \frac{\text{RMS miss distance (total yards)}}{\text{Range/1000}}.$$

The RMS miss distance figures for the four ships from which tracking data were collected are shown in Table 4. The miss distance RMS per 1000 yards of range is considered to be the most appropriate overall measure of sonar tracking accuracy. In conjunction with range and bearing error, sonar miss distance appears to be a measure that should be included in a PPAS.

Very significant differences in tracking accuracy were present between ships during initial exercises; however, these differences decrease in subsequent exercises. It is inferred that initial differences are indicative of differences in experience or the time interval since operators had sonar practice. Figure 2 illustrates the initial disparity in sonar tracking accuracy and the performance leveling achieved with practice. With very little practice the differences were reduced. This information could be of considerable value in determining how often Fleet ASW teams should utilize the trainers.

<u>Sonar Doppler Error</u>. The SQS-26CX Sonar used with the 14E19 Trainer can be used to measure sonar doppler and determine increasing or decreasing range rate, referred to as opening (down) or closing (up) doppler. When the target tracking console (TTC) operator positions the doppler cursor on the target doppler indicator (TDI), he is provided with a readout of doppler (range rate) in knots. On the 14E19 Trainer, doppler error is displayed on the instructor's console; this error was recorded by the 14E19 Data Collection Program by reading the doppler error computer output word directly at 10-second intervals.

Sonar doppler is input to the fire control system at each NDT and should be measured with the same constraints imposed in measuring bearing and range error. An additional constraint is that it should only be measured when the target tracking console is in control of either the A-scan or B-scan. The $\overline{X}$, σ, and RMS for doppler error were calculated for each exercise in which the 14E19 and 14A2 Trainers were run in joint mode. These data, which are shown in Table 5, indicate that doppler error did not decrease with practice. This suggests that proper positioning of the TDI cursor may be a difficult task for the operator or that TDI cursor positioning is not properly understood by individual operators. This would make doppler error an important measure for application to the PPAS.

As with sonar tracking error, the $\overline{X}$ and σ for doppler error are more descriptive of specific performance deficiencies, while the RMS provides a more appropriate overall measure.

Table 4

Sonar Tracking Error Miss Distance

Ship	RMS (total yards)	RMS (mils)
	Exercise Category 2	
A	843	88.6
B	390	48.8
C	274	30.8
F	360	55.4
	Exercise Category 3	
A	415	57.6
B	206	21.7
C	103	11.57
	Exercise Category 4	
A	330	36.7
B	161	21.8
C	176	19.6
F	106	19.3
F[a]	174	32.8

[a]For ship F there was no exercise Category 3 data available; therefore, an additional Category 4 exercise was recorded.

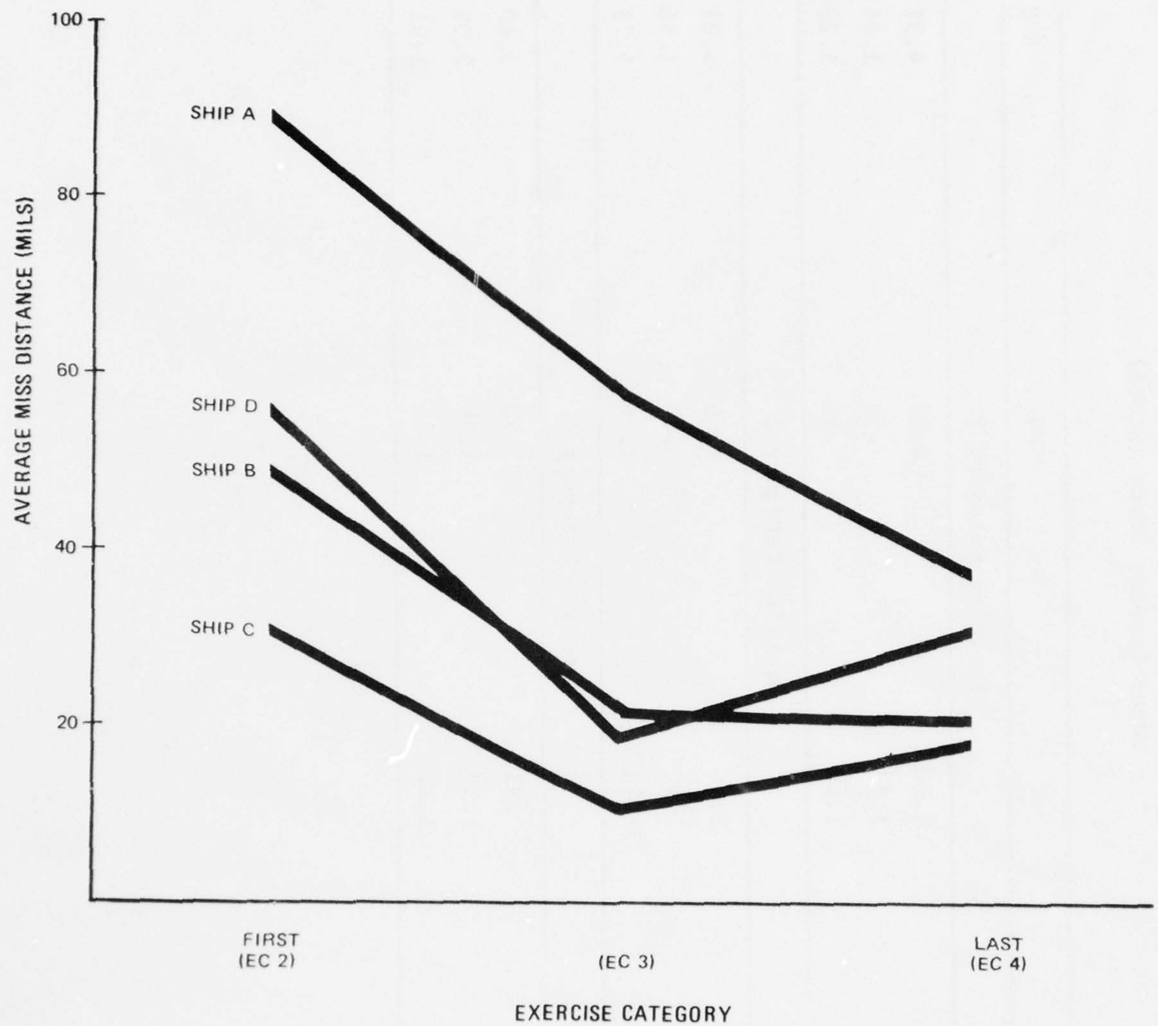

Figure 2. Average sonar miss distance (mils) for each exercise category.

Table 5

Sonar Doppler Error (knots)

Ship	$\overline{X}$	σ	RMS
	Exercise Category 2		
A	1.66	4.07	4.31
B	1.77	.56	1.85
C	1.69	.60	1.79
	Exercise Category 3		
A	2.04	4.66	5.01
B	1.50	.44	1.56
C	1.43	1.16	1.78
	Exercise Category 4		
A	.91	3.53	3.60
B	1.59	1.38	2.09
C	1.28	1.46	1.91

The SQS-23 Sonar used with the 14A2 Trainer in independent mode does not have doppler tracking capability. Doppler is recognized as an aural signal and reported over the 61JS sound-powered phones and 29MC circuit as "up" or "down" doppler. For the SQS-23, doppler error was considered to be a sonar communications error.

Sonar Time Measures

Four time measures were evaluated for the sonar subteam. The four measures are target detection time, regain contact time, response to lost contact, and time to resolve multiple echoes (M/E). A summary of results for the six teams on which these measures were obtained is presented in Table 6.

Target Detection Time and Regain Contact Time. Target detection time and regain contact time are essentially the same measure; target detection time refers to the first time contact is acquired, while regain contact time refers to times when contact is gained following lost contact. These measures are not really meaningful under the current circumstances of ASW team training; therefore, they are not considered to be appropriate for PPAS use. (The current practice is to keep the target deactivated on the sonar display until the target has reached a range at which it will appear distinctly when it is activated.)

Time to Resolve Multiple Echoes. Time to resolve multiple echoes appears to be the most appropriate sonar subteam time measure. Multiple echoes are simulated on the 14A2 Complex by activation of a second submarine on the sonar displays at the same position as the target submarine, but dead in the water. This results in a display of diverging multiple echoes, in which the second submarine represents a decoy. Instructors use these echoes in two ways. In the first, they are generated until the correct target is determined, then the decoy is deleted from the sonar display. (The decoy may also be removed if the instructor decides the team cannot handle multiple echoes and he wants the exercise to continue.) In the second, the target submarine is placed in a dive below sonar layer depth so that only the decoy is displayed. In this case, the team is expected to determine that the track is a decoy and to go to LOST CONTACT procedures.

In the multiple echo procedures the sonar subteam immediately reports multiple echoes to CIC. Then, the operator alternates between tracking the first signal, designated "Alpha," and the second signal, designated "Bravo," to determine which echo return is the submarine. (This determination is made aurally through judgments of signal strength, echo quality, and doppler.) Large range and bearing errors are generated while the operator is tracking the decoy. The error magnitudes increase and decrease as the operator alternates between "Alpha" and "Bravo." At each NDT he reports range and bearing for one signal or the other, as appropriate. Upon resolution, he reports which track is correct and continues tracking, or he reports that he has lost contact and sets the sonar in SEARCH.

Time to resolve multiple echoes is currently determined by the instructors by listening to sonar/CIC communications. For this research, it was determined through an analysis of printouts of range and bearing information. This information could be recorded automatically by having the computer carry out a similar

Table 6

Sonar Subteam Time Measures

Ship	Target Detection Time (sec)	Regain Contact Time (sec)	Resolve M/E Time (sec)	Response to Lost Contact (sec)
		Exercise Category 2		
A	34	21	Unresolved	N/A
B	30	47	N/A	26/28
C	60	2	170	41
D	31	N/A[a]	143	N/A
E	69	21	N/A	N/A
F	37	N/A	Unresolved	Didn't respond
		Exercise Category 3		
A	72	45	Tracked wrong target	44
B	49	240	190	25
C	37	N/A	185	24
D	19	N/A	N/A	N/A
E	57	N/A	210	57
		Exercise Category 4		
A	30	N/A	142	N/A
B	19	46	90	70
C	50	N/A	165	N/A
D	80	N/A	170	N/A
E	10	N/A	N/A	N/A
F[b]	37	N/A	N/A	N/A
F	45	12	55	104

[a]N/A indicates that for various reasons time data could not be collected.

[b]For ship F there was no exercise Category 3 data available; therefore, an additional Category 4 exercise was recorded.

analysis. The start time (that is, the time at which the decoy is activated) could easily be determined and recorded in the trainer's computer. However, the terminate time is more difficult to determine, although it could be established through fairly simple logic. If the operator's range and bearing errors were fairly small (for example, less than 250 yards on the 5000-yard scale) where the decoy was deactivated, the operator would be judged to have correctly resolved the situation. The time at which the multiple echoes were resolved would be the time at which range and bearing errors were last within nominal error limits prior to decoy deactivation. If errors were abnormally large at the time the decoy was deactivated, the operator would be judged to have not correctly resolved the situation. To simulate a situation in which the target submarine dives below the sonar layer, the target submarine would be deleted from the display first. The time at which the sonar is placed in SEARCH would denote the time at which the operator correctly determined that he has lost contact. If the decoy was deleted from the display before the sonar was placed in LOST CONTACT, the operator would be judged to have not correctly resolved the situation.

Table 6 shows the results of the multiple-echo measures. These results suggest that the sonar subteam could be evaluated on two counts. First, they could be evaluated from a procedural standpoint, scoring positively if multiple echoes were correctly resolved and negatively if they were not. Second, they could be evaluated in terms of time to resolve multiple echoes. Time measures show significant differences in the amount of time taken to resolve multiple echoes, although the sample is too small to provide meaningful statistical data. The time measure reflects team efficiency in multiple-echo procedures. This measure appears to be appropriate for use in the proposed PPAS.

Response to Lost Contact. Lost contact time represents the inverse of the target detection time measure. This measure, like target detection time, is probably not meaningful in the context of team training and therefore is not suitable for PPAS use. The large number of lost contact times missing from Table 6 is an indication of the difficulty of obtaining this measure. In some exercises the target is deleted by instructor action. In others, the target is placed in a dive, and the target signal is gradually attenuated as a function of environmental and performance factors. In this case the reference time cannot be accurately determined.

Sonar Procedures Measures

Two methods were used to derive quantitative measurement data on sonar operational procedures. First, sonar instructors were provided with sonar communications procedures checklists that were specifically devised to obtain quantitative measures. Second, for the 14E19 and 14A2 joint exercises, the 14E19 Data Collection Program recorded all switch settings on the SQS-26CX Sonar Consoles. Numerous difficulties were encountered that prevented the collection of reliable data; however, enough data were taken to demonstrate that such measures can be obtained.

The frequency of procedural errors provides a direct measure of sonar subteam performance; however, it appears to be infrequently used. In most cases the instructors reported that "there were no errors to be recorded." The errors that were recorded indicate that several factors must be considered in obtaining frequency measures of procedural errors.

First, ASW team training deemphasizes basic operator skills and emphasizes the team's ability to track the target, resolve M/Es, and integrate sonar data into a coordinated ASW attack. Consequently, the sonar instructors established initial equipment settings and allowed little variance in operational procedures during the exercise. Their direction allowed very few operational errors to be made.

Second, switch positions must be interpreted relative to tactical conditions. All the procedure errors that were recorded indicated a need to do this. One error involved the sonar display RANGE SCALE control setting. Usually, the sonar scale is set at XXKYDS. When aircraft-vectored attacks (VECTACS) are conducted at limited ranges (but still greater than the sonar range scale setting), this establishes a DATUM position for the target, and the sonar operator should shift to a longer range scale. In some instances, operators failed to do this. The second--and most commonly recorded--switch positioning error was shifting too late from SEARCH and LOST CONTACT to CONTACT and TRACK. The third error of this type was to leave the sonar in CONTACT/TRACK once contact was lost.

In order to provide automated recording of the first type of switch positioning error, software logic must be devised to record the VECTAC position and determine the appropriate range-scale setting. For the other errors, logic must note the time of activation or deactivation of the target on the sonar display, and the time of LOST CONTACT/CONTACT or SEARCH/TRACK setting. The time it takes to get an appropriate setting can be compared to criterion reference times to determine if the time of changing the switch positions is late and should be registered as a procedural error. These examples of procedural errors illustrate the necessity for extensive programming to interpret switch settings as part of an automated performance measurement system.

The close directive control assumed by sonar instructors makes it difficult for them to maintain fully reliable records of procedural errors by recording them manually. This suggests that the development of automated recording of procedural errors would be beneficial in evaluating subteam performance. It would provide trainees with immediate feedback and collect data for a PPAS. In the PPAS, automated recording would help define those procedural errors that occur most frequently and represent specific deficiencies within Fleet ASW teams.

Sonar Communications Measures

Communications error data were equally as difficult to obtain as procedural error data, and relatively few errors were recorded. However, on two exercises data were obtained for some communications errors, and evaluation comments from instructors were acquired for several others. These data suggest that if a method could be devised for automated recording of communications errors, such as an automated voice-recognition system, quantitative measures could be developed that would provide a very direct measure of performance proficiency for PPAS utilization. Initially, three measures of communications were proposed:

1. Frequency of omitted data items.
2. Frequency of late data items.
3. Frequency of incorrect data items.

The frequency of incorrect data items does not appear to be a relevant measure. Communications from sonar are usually concerned with reporting discrete events, for example, lost contact or multiple echoes. Range and bearing are reported directly as obtained from console readouts. The operators do not calculate values, such as cone-of-courses, where considerable inaccuracies might be generated. As a result, few errors would be found on this measure.

The frequency of omitted data items appears to be the most important measure. Specific reports for the following items should be transmitted over the 61JS or 29MC circuits:

1. Contact/lost contact.
2. Regain contact.
3. Range and bearing at each NDT.
4. Multiple echoes.
5. No echoes.
6. Hydrophone effects (or torpedo and bearing).
7. Approaching baffles.
8. Doppler.
9. Classification of contact.

The frequency of omitted or late data items provides direct measures of adherence to communications doctrine.

UB Plot Subteam Measures

The key personnel comprising the UB plot (fire control) subteam are the ASW fire control officer, attack plotter operator, and the ballistics computer operator.

UB Plot Accuracy Measures

Target Motion Analysis (TMA) Course and Speed Error. Target motion analysis course and speed data were recorded by the 14A2 Computer Data Collection program and subsequently analyzed by a separate data reduction program. The observed data points for TMA errors were the cursor positions for target course and speed on the attack plotter console. The attack plotter operator inserts course and speed estimates by aligning his cursors to best fit the sonar NDT points on the console. The reference data points were the actual course and speed of the target from the main trainer program. Ideally, course and speed error should be sampled following each sonar NDT input to fire control; however, they were recorded at 10-second intervals as were the sonar data.

Since TMA is based on sonar input, it is obvious that the conditions applying to sonar error apply to TMA error. That is, recording should not begin until two or three pings after contact, and TMA error should be recorded while in CONTACT but not during multiple-echo procedures. Additionally, course or speed error is not meaningful during target course or speed maneuvers, since course or speed is continuously changing until the maneuver is complete.

In order to obtain overall scores for TMA accuracy, the $\overline{X}$, σ, and RMS values were calculated for TMA course and speed errors; these values are presented in Tables 7 and 8. However, caution should be used in interpreting the statistical values. Typically, two to four course estimates are made between

Table 7

TMA Course Error, (degrees)

Ship	$\overline{X}$	σ	RMS
	Exercise Category 2		
A	-19.00	6.37	20.00
B	- 8.32	13.78	15.80
C	11.88	5.86	13.06
	Exercise Category 3		
A	- .13	0	.13
B	3.50	4.90	5.68
C	-17.28	8.30	18.99
	Exercise Category 4		
A	-10.05	0	10.05
B	.23	0	.23[a]
	(6.56)	(0)	(6.56)
C	7.95	9.42	11.72
F	- 4.46	9.62	8.13
F	12.06	10.88	15.96

Note. Ships D and E did not have fire control systems; consequently, the teams did not use that equipment in the trainer.

[a] The first value is for estimate prior to submarine maneuver, and the second (shown in parentheses) is for estimate after maneuver.

Table 8

TMA Speed Error (knots)

Ship	$\overline{X}$	σ	RMS
	Exercise Category 2		
A	7.37	.13	7.40
B	- 3.21	2.86	4.25
F	3.88	2.06	4.33
	Exercise Category 3		
A	- 2.13	0	2.13
B	-12.54	.65	12.56
C	-11.63	.04	11.63
	Exercise Category 4		
A	10.09	0	10.09
B	2.91	0	2.91
C	-12.68	.89	12.71
F	5.97	0	5.97
F	4.24	9.00	9.60

Note. Ships D and E did not have fire control systems; consequently, the teams did not use that equipment in the trainer.

the time of contact and the first weapon firing, with the first adjustment occurring about 30 to 60 seconds after contact. Occasionally, an original estimate may be set based on a CIC estimate, and no readjustment will be made following contact if the TMA course cursor appears to be a good fit to the subsequent NDT points. This is very likely if there is little time between contact and weapon firing or very inconsistent NDT inputs to fire control. In this case the σ would equal zero, but it would not necessarily reflect good performance by the attack plotter operator. One operator's errors on initial TMA may be considerably reduced by time of fire, which is desirable; still, a large $\overline{X}$ would result. The $\overline{X}$ of another operator may be smaller but only reflect self-canceling errors. For this reason the RMS, in addition to indicating TMA at time of fire, is helpful in showing the overall effect of TMA estimates. For diagnostic information, a generated plot of TMA estimates and actual submarine positions would show specific points where course and speed estimates improved or degraded. The $\overline{X}$ and σ values for course and speed errors should be used in conjunction with TMA error plots to ensure appropriate interpretation of the values. Additionally, the $\overline{X}$ and σ should be compared to the course and speed at time of fire. As with sonar bearing and range error, TMA course and speed error can be converted to miss distance, which provides a more comprehensive or generalized measure.

TMA Miss Distance. TMA miss distance represents the combined effect of TMA course and speed error. It is calculated from generalized equations along with the sonar tracking miss distance. TMA miss distance could be used in place of course RMS and speed RMS to provide a single TMA (UB plot subteam) accuracy score. Data for TMA miss distance are provided in Table 9.

The very significant differences ($p < .01$) in TMA accuracy sampled in course and speed errors and in miss distance cannot be attributed to attack plotter operator performance. The ability to estimate target course and speed is directly related to the variability of sonar range and bearing inputs. The greater the variability in sonar tracking accuracy, the more difficult it is for the plotter operator to estimate target course and speed, although the exact relationship between these two measures has not been established. A procedure must be developed for converting TMA course, speed, and miss distance scores to scores that are adjusted for variance in sonar inputs. This procedure might be based on the difference between the TMA solution and a least squares solution to sonar NDT data points on the UB plot attack plotter.

Manual Offsets Error. Setting the TMA manual offsets for an ASROC attack is an important function of the ballistics computer operator at the MK38/53 Fire Control Console. The operator inserts a manual bearing offset and manual range offset that together offset the weapon entry point (WEP) generated by fire control. The offset values correspond to distance in yards. The operator inserts the manual offsets just before the weapon is fired. He does this for two reasons. First, the submarine may make a last-second maneuver just before the attack. The manual offsets allow the operator to correct for this maneuver. Second, the torpedo has a specific search pattern that controls its direction after it is activated at the preset search depth. The operator may insert manual offsets to account for the search pattern so that the torpedo will be more effectively directed towards the submarine. The offset values are directly dependent on the problem geometry. The computer-generated WEP does not account for the torpedo search pattern.

Table 9

TMA Miss Distance Averages

Ship	RMS (yards)	RMS (mils)
	Exercise Category 2	
A	356.6	37.5
C	236.7	26.6
F	167.6	25.8
	Exercise Category 3	
A	70.0	9.7
B	507.0	53.7
C	444.9	50.0
	Exercise Category 4	
A	416.0	46.0
B	115.0	15.5
C	486.9	54.1
F	182.4	33.2
F	141.6	26.6

Note. Ships D and E did not have fire control systems; consequently, the teams did not use that equipment in the trainer.

Algorithms can be developed to compute the ideal offsets when the manual offset controls are set; these algorithms would be based on the firing bearing, target course and speed, and the torpedo search pattern. Comparison of the actual settings to the ideal settings would provide measures of manual bearing and range offset errors for a given attack. These measures could be converted to a total manual offset miss distance error. This overall measure would provide a second accuracy measure that, along with TMA miss distance, would be used to evaluate fire control operators. Total manual offset miss distance and error would provide an appropriate measure for PPAS utilization.

UB Plot Time Measures

Two UB plot time measures were considered, TMA solution time and TMA adjustment time. These measures reflect essentially the same performance parameter under different conditions. Therefore, they are discussed separately. A summary of time measures is presented in Table 10.

TMA Solution Time. TMA solution time measures the amount of time required for the attack plotter operator to establish an initial solution. For this study, "start" was the initial contact time. "Terminate" was the time at which the TMA course and speed cursor were set to ensure that course error was 20 degrees or less, and course and speed error remained stabilized for more than 10 seconds or for two NDT data points.

Ability to obtain TMA solution time was limited by two conditions. First, the target could not be maneuvering immediately before the initial solution. In this event the measure was voided. Second, TMA course error could not be < 20 degrees at the time of contact. As noted in the discussion of TMA course and speed error, the operator can set his cursors based on CIC initial estimates of target course and speed in preparation for a rapid TMA solution once contact is obtained. The terminate time will be the time of the first stabilized cursor adjustment following contact.

TMA Readjustment Time. TMA readjustment time is the equivalent of TMA solution time following a target maneuver or multiple echoes. The start time was either the time at which the target completed its maneuver or the time at which the decoy was deleted from the sonar displays. The observed time was established through the same set of criteria used for TMA solution time. In any single exercise, several measures of TMA solution or readjustment time might be obtained, due to several attacks or target maneuvers. In this case, the appropriate value for providing a time measure of UB plot subteam performance would be the arithmetic average of the measures. The term "TMA convergence time" will be used to refer to both TMA solution and TMA adjustment times. Average TMA convergence time provides a good measure for PPAS use.

UB Plot Communications Measures

The same difficulties that were experienced in collecting sonar communications data were encountered in UB plot; consequently, almost no communications error data were collected. The frequency of omitted or late data items could provide valuable inputs to PPAS. However, it is almost impossible to obtain these measures until a system is developed for automatically recording them. When a system is developed, the following items of UB plot to CIC communication information should be monitored:

Table 10

UB Plot Subteam Time Measures

Ship	Exercise Category 2	3	4
	TMA Solution Time (seconds)		
A	139	51	57
B	N/A[a]	73	59
C	164	164	78
F	80	N/A	40
	TMA Adjustment Time (seconds)		
A	N/A	N/A	56
B	N/A	74	85
C	78	54	64
F	149	27	70

[a]N/A indicates that for various reasons the time measures were not available.

1. Report TMA solution (with each update).
2. Report weapon selection.
3. Report gyro selection.
4. Request permission to fire.
5. Report standby.
6. Report weapon fire away.
7. Request director (request the fire control director radar to track an ASROC shot and obtain an accurate fix on the actual WEP point).

UB Plot Procedures Measures

During the entire group of exercises, only one UB plot error was noted by the instructors, although it was noted on three exercises: the operator failed to use the director control function. This function provides fire control-aided tracking, which means that it directs the TMA solution course and speed back to the sonar to assist in tracking. A measure of procedural errors would be significantly more critical in more complex sonar exercises involving bottom bounce or convergence zone modes of operation. Data should be collected on such exercises to determine the degree to which procedural errors increase.

On the basis of the instructors' observations, it would appear that UB plot operational errors rarely occur; however, an evaluation of exercise data indicates that this is not necessarily so. For example, the TMA solution is greatly degraded by multiple echo procedures conducted by the sonar subteam. When multiple echo procedures are being conducted, the attack plotter operator should place the fire control system in the position keeping (PK) mode. In this mode, the ballistic solution is maintained, and new sonar range and bearing data are not accepted. When multiple echoes are resolved, the UB plot console should be reset to the attack mode to receive sonar data. On some exercises, the operator failed to follow this procedure, and a large TMA error resulted. In others, the ballistics computer operator failed to insert appropriate bearing and range manual offsets. As with the sonar subteam, UB plot subteam procedural errors could be recorded through automatic switch monitoring. A count of the relative frequencies of procedural errors should be very helpful in diagnosing the specific types of errors that are commonly committed by the ASW teams. This is the type of information that should be collected by a PPAS.

USE OF STG MEASUREMENT DATA IN A PERFORMANCE PROFICIENCY ASSESSMENT SYSTEM

Applicable STG Performance Measure

Evaluation of the individual performance measures for the sonar and UB plot subteams delineated in the preceeding section shows that the following STG-related measures would be applicable for PPAS use:

1. Sonar Billet Measures

    a. Sonar tracking range error.
    b. Sonar tracking bearing error.
    c. Sonar tracking miss distance.
    d. Sonar doppler error.
    e. Time to resolve M/E.
    f. Frequency of communications errors.
    g. Frequency of procedural errors.

2. UB Plot Billet Measures

    a. TMA course error.
    b. TMA speed error.
    c. TMA miss distance.
    d. Manual offsets miss distance.
    e. TMA convergence time.
    f. Frequency of communications errors.
    g. Frequency of procedural errors.

Major Factors Limiting Use of the STG Data

Several factors limit the use of the performance measurement data that are available from ASW team exercises. First, the data are not comprehensive. In the evaluation of the individual measures, it was noted that these measures may provide "indices" of STG performance proficiency, but they do not show all aspects of performance.

Second, the manner in which the 14A2 ASW Team Trainer is used by FLEASWTRACENPAC and the ASW Fleet must be taken into account. Currently, all of the teams assigned to ASW surface ships are required to undergo training at regular intervals. Their Commanding Officers can require additional training if they decide it's needed. Normally, the ship's officers decide which team members will man the various operator stations. The usual practice is to rotate the team members among the two or three positions that they might assume at sea, to ensure that each individual on the team receives all relevant practice. Additionally, personnel are frequently reassigned to a new ship or position. These factors could create a problem in attempting to obtain representative samples for Fleet evaluation. Subroutines must be incorporated within the various procedures for data summarization that account for some ships or individuals having repeated training sessions, while others have relatively few.

Third, some measures cannot always be attributed to a single individual or station. Good examples of this are found in counting procedural errors at the sonar or UB plot consoles. Usually, the sonar supervisor and Firing Petty

Officer (FPO) exercise close direction over the individual console operators, especially with respect to control settings; consequently, it usually is not possible to determine who has committed a control setting error. In this study, all procedural errors were attributed to the individual console operators and to the sonar supervisor or FPO, as appropriate.

Finally, it was assumed that the variables that tend to enhance or diminish certain aspects of performance in ASW exercises (for example, problem geometry and tactics) would tend to be self-canceling when averaged over a large enough sample, and that this would result in representative measures of performance. Consequently, while the performance measures can be extracted for use in a PPAS to provide generalized indices of Fleet proficiency, they cannot provide a comprehensive evaluation of an individual exercise or ship. Thus, data for an individual ship can only be fully understood in the context of all the conditions that prevailed for each exercise. As a result, the performance measurement data will show specific areas of team weaknesses or strengths and identify specific deficiencies at the Fleet level; but by themselves they cannot identify causes for these deficiencies.

Procedures for PPAS Data Summarization, Printout, and Evaluation

The data to be summarized and printed out for use with a PPAS are described in two categories: (1) detailed level data and (2) summary level data. The ability to obtain these data depends upon implementation of a comprehensive performance measurement and data collection system within the ASW team trainer to monitor team, subteam, and individual actions and store all data for reduction, evaluation, and printout after the exercise is completed. The following discussion assumes that the specific hardware and software requirements to collect all such data can be met.

Preparation and Printout of Detailed Data

The first stage of data reduction for PPAS use is to obtain detailed level-of-performance measures for each individual and ship. Figures 3 and 4 show examples of (hypothetical) detailed level statistics for the sonar and UB plot subteams. Note that the data are referenced in the 14E19 (SQS-26CX Sonar) Trainer or MK53 Console of the UB plot fire control system, as appropriate. Detailed level and resultant summary data should be maintained separately, and separate data printouts and memory storage should be established for each sonar trainer (for example, 14E23 or 14E24) and the MK 38 Fire Control in a manner analogous to that shown for the 14E19 Trainer and MK 53 Fire Control console.

Each performance measure should be attributed to a specific individual depending on the billet positions that are manned during the exercise. For example, the RMS doppler error and RMS sonar track miss distance are assigned to either the B-scan operator or the A-scan operator, depending on who was in CONTACT and tracking the target submarine. Some measures are assigned to two individuals. For example, the time, procedures, and communications measures for the sonar subteam are assigned to both the console operator and the sonar supervisor. Although the errors are made at the individual consoles, the sonar supervisor has direct control of operator actions affecting these three measures, and he is, therefore, at least partially responsible for the errors. The values for the sonar supervisor appear in parentheses in Figure 3 to indicate that they are being noted twice but not summed twice. The sum of all the scores for the console operators is scored against the sonar supervisor.

	Personnel			Accuracy		Time	Procedures	Communications
Ship/Exercise	Name	Rate/Pos[a]	Soc. Sec. No.	RMS Miss Distance (mils)	RMS Doppler Error (knots)	Time To Resolve M/E	Freq. Proc. Errors	Freq. Comm. Error
Ship 1								
Exercise 1	John Doe 1	STG 1/SPR	111-11-1111	--	--	(Unresolved)	(8)	(14)
	John Doe 2	STG 2/A	222-22-2222	--	--	--	1	3
	John Doe 3	STG 3/B	333-33-3333	95.4	--	Unresolved	3	4
	John Doe 4	STG 1/TTC	444-44-4444	88.6	4.31	--	4	7
Exercise 2	John Doe 1	STG 1/SPR	111-11-1111	--	--	(Incorrect)	(6)	(10)
	John Doe 2	STG 3/A	333-33-3333	91.0	--	--	1	2
	John Doe 3	STG 1/B	444-44-4444	93.7	--	--	2	3
	John Doe 4	STG 2/TTC	222-22-2222	57.6	5.01	Incorrect	3	5
Exercise 3	John Doe 1	•	•	•	•	•	•	•
	John Doe 2	•	•	•	•	•	•	•
	John Doe 3	•	•	•	•	•	•	•
	John Doe 4	•	•	•	•	•	•	•
Exercise N	John Doe 1	STG 1/SPR	111-11-1111	--	--	(142)	(4)	(8)
	John Doe 2	STG 2/A	222-22-2222	45.6	--	--	0	1
	John Doe 3	STG 3/B	333-33-3333	42.1	--	142	1	4
	John Doe 4	STG 1/TTC	444-44-4444	36.7	3.60	--	3	3
Ship 2 Exercise 1 Exercise 2 Exercise 3 Exercise N	Same Data			Same Data	Same Data	Same Data	Same Data	Same Data
Ship N Exercise 1 Exercise 2 Exercise 3 Exercise N	Same Data			Same Data	Same Data	Same Data	Same Data	Same Data

[a]Abbreviations: SPR = Supervisor, A = A-scan Operator, B = B-scan Operator, TTC = Target Tracking Console Operator.

Figure 3. Hypothetical detailed proficiency data for sonar billets.

Ship/Exercise	Personnel: Name	Personnel: Rate/Pos[a]	Personnel: Soc. Sec. No.	Accuracy: RMS TMA Miss Distance (mils)	Accuracy: Manual Offsets Miss Distance (yards)	Time: TMA Convergence Time (sec)	Procedures: Freq. Proc. Error	Communications: Freq. Comm. Error
Ship 1								
Exercise 1	John Doe 5	STG 1/FPO	555-55-5555	--	--	--	--	--
	John Doe 6	STG 2/AP	666-66-6666	37.5	--	139	7	10
	John Doe 7	STG 3/BC	777-77-7777	--	130	--	--	--
Exercise 2	John Doe 5	STG 1/FPO	555-55-5555	--	--	--	8	12
	John Doe 6	STG 2/AP	666-66-6666	46	--	73	--	--
	John Doe 7	STG 3/BC	777-77-7777	--	100	--	--	--
Exercise N	John Doe 5	•	•	--	--	--	3	8
	John Doe 6	•	•	9.7	--	57	--	--
	John Doe 7	•	•	--	70	--	--	--
Ship 2								
Exercise 1	Same Data	Same Data		Same Data	Same Data	Same Data	Same Data	Same Data
Exercise 2								
Exercise 3								
Exercise N								
Ship N								
Exercise 1	Same Data	Same Data		Same Data	Same Data	Same Data	Same Data	Same Data
Exercise 2								
Exercise 3								
Exercise N								

[a]Abbreviations: FPO = Firing Petty Officer, AP = Attack Plotter Operator, BC = Ballistics Computer Operator.

Figure 4. Hypothetical detailed proficiency data for UB plot billets.

The second stage of data reduction is to summarize data at individual and ship levels across all exercises. Figure 5 shows an example of ship-level statistical data for the sonar billets. The data for UB plot billets are summarized in the same manner. In this summation, data are divided into two categories; measures for the first exercise for each individual, and measures for the last exercise (or average of the last $\underline{n}$ exercises) for each individual. This refers specifically to the first and last exercises in which the individual is at a certain position in which a given measure is taken. For example, a comparison of Figures 3 and 5 shows that the first and last RMS doppler error scores attributed to John Doe 4 correspond to the first and last exercises in which he occupied the TTC console operator's position. The data from the first exercises represent pretraining proficiency--that is, the level of performance that has been maintained since the last training was received. The data from the last exercises represent the proficiency level that is achieved at the end of ASW team training. In the discussion of sonar tracking miss distance, it was shown that pretraining and posttraining scores may be significantly different.

Once scores are categorized into pretraining and posttraining groups, they can be averaged to represent ship scores in each category. For time, procedures, and communications measures, the ship's score would be the simple arithmetic average ($\overline{X}$). Measures that are RMS values must use a slightly different procedure. Where there are several estimates of RMS for the same individual, such as RMS for each exercise, or several independent values for each ship, the best estimate of the team value is the pooled variance (Sp^2) (Dixon & Massey, 1957). For this particular application, the pooled variance is the pooled RMS (RMS_p), which is obtained as follows:

$$S_p = \left[\frac{S_1^2 + S_2^2 + \ldots S_k^2}{k}\right]^{1/2} = RMS_p.$$

An example of this is shown by average pretraining sonar miss distance for ship 1 in Figure 5, where

$$\left[\frac{(57.6)^2 + (88.6)^2}{2}\right]^{1/2} = 74.7.$$

Regardless of the procedure ($\overline{X}$ or RMS) used for each measure, the user of these data (the Navy personnel manager) may interpret the resultant value as simply a ship average. The ship averages can then be averaged to obtain a total sample average. For purposes of illustration, it is assumed that data would be summarized over three-month periods. At the FLEASWTRACENPAC, approximately 25 ships go through the trainers each quarter. Quarterly averages would be obtained in the same manner as ship averages, using ships' scores as individual samples. The quarterly average for pretraining proficiency of sonar miss distance, for example, would be obtained as follows:

Ship Personnel		Accuracy: First RMS Miss Distance (mils)	Accuracy: Last RMS Miss Distance (mils)	Accuracy: First RMS Doppler Error (knots)	Accuracy: Last RMS Doppler Error (knots)	Time: First Time to Resolve M/E (sec)	Time: Last Time to Resolve M/E (sec)	Procedures: First Freq. Proc. Errors	Procedures: Last Freq. Proc. Errors	Communications: First Freq. Comm. Errors	Communications: Last Freq. Comm. Errors
Ship 1											
John Doe 1	111-11-1111	--	--	--	--	(Unresolved)	(142)	(8)	(4)	(14)	(8)
John Doe 2	222-22-2222	57.6	45.6	5.01	4.0	Unre-	--	1	0	3	1
John Doe 3	333-33-3333	--	--	--	--	solved	142	3	1	4	4
John Doe 4	444-44-4444	88.6	36.7	4.31	3.60	--	--	4	3	7	3
Total Ship Average		74.7	41.4	4.67	3.81	--	142	8	4	14	8
Ship 2											
John Doe 5	555-55-5555	42.8	15.3	1.7	1.5	140	195	(10)	(6)	(12)	(5)
John Doe 6	666-66-6666	--	--	--	--	--	--	2	1	3	1
John Doe 7	777-77-7777	--	--	--	--	--	--	4	2	4	1
John Doe 8	888-88-8888	54.1	26.8	2.0	2.6	200	135	4	3	5	3
Total Ship Average		48.8	21.8	1.85	2.1	170	165	10	6	12	5
Ship N											
John Doe 9	999-99-9999	35.2	13.5	1.3	1.3	115	90	(12)	(3)	(16)	(7)
John Doe 10	100-10-1010	--	--	--	--	--	--	3	0	4	1
John Doe 11	110-11-1111	70.0	23.7	2.2	2.3	171	130	5	1	4	3
John Doe 12	120-12-1212							4	2	8	3
Total Ship Average		55.4	19.3	1.8	1.9	143	110	12	3	16	7
Pretraining Proficiency Level		60.6		3.1		156.5		10		14	
Post-training Proficiency Level			29.2		2.7		139		4.3		6.7

Figure 5. Hypothetical ship level proficiency data for sonar billets.

$$\text{quarterly sonar Miss Distance (RMS)} = \left[\frac{(74.7)^2 + (48.8)^2 + (55.4)^2}{3}\right]^{1/2} = 60.6.$$

The detailed level statistics and ship level statistics could be provided as data printouts in the formats shown in Figures 3 to 5. If these data are to be available for the PPAS, they will have to be generated through post-exercise data reduction and stored on disk or in memory core at the levels of reduction shown. The data would then have to be transferred to tape and retrieved on a periodic basis from the various team trainer locations.

Use of Detailed Level Data in the PPAS

The detailed level data for individuals and for ships are intended for use in providing appropriate information concerning specific training deficiencies as they relate to (1) personnel assignment, selection, and utilization; and (2) shipboard and school training of STG personnel. The data obtained from ASW team training exercises cannot in themselves provide this information. They must be collected on tape and integrated into a more extensive, central PPAS data base. The social security number of each individual provides the means by which the PPAS can obtain specific demographic data, personnel assignments, length of service, type and extent of training, specific courses taken, achievement scores, or other information. Relationships between various ASW team proficiency measures and numerous variables involved in training, personnel assignment, selection, and utilization can be established through statistical procedures such as analysis of variance, correlation procedures, and time series analysis. These procedures cannot be defined within the scope of this effort, since the specific types of demographic data that would be available to a PPAS data base have not yet been defined.

Preparation and Printout of Summary Data

Summary data should be partitioned into two groups, one for performance proficiency and the other for diagnostic deficiency. Suggested performance proficiency data printouts for sonar and UB plot subteam billets are shown in Figures 6 and 7. Like the ship level statistics data, these data are divided into pretraining and posttraining proficiency data. Comparison of Figures 6 and 7 shows that the quarter averages for the various measures are taken directly from the ship level statistics, as previously described. Quarterly averages from the immediately preceding quarter should be provided to permit a direct comparison of changes in proficiency levels. During any given quarter, a relatively small sample of Fleet ships may receive training, and these ships may not be fully representative of general Fleet proficiency levels. To account for this, data should be summarized over the last three or four quarters and presented as long-term averages. As with the quarterly averages, the long-term averages should be updated on a quarterly basis. Providing both quarterly and long-term averages allows a general overview of both short-term effects and long-term trends in proficiency for the various performance areas. Along with the averages for the several measures, the average time (months) between exercise training sessions for ships' teams should be shown. This information may be helpful in determining the level of training (amount of training, time between training sessions, or training complexity) that is appropriate in maintaining desired proficiency levels throughout the Fleet.

Statistical Parameters	Measurement Categories					
	Average Time Between Exercises	Accuracy		Time to Resolve M/E (sec)	Proc. Errors (freq)	Comm. Errors (freq)
		Sonar MD (mils)	Doppler Error (knots)			
Posttraining Proficiency						
Quarter Averages	6.2	25.2	2.7	139	4.3	6.7
Past-Quarter Averages	6.0	24.0	3.6	152	6.0	10
Long-Term Averages	6.0	25.0	3.4	148	6.5	12
Pretraining Proficiency						
Quarter Averages	6.2	60.6	3.1	156.5	10	14
Past-Quarter Averages	6.0	58.5	3.8	156.7	11	15
Long-Term Averages	6.0	60.0	3.6	173.0	10	10

Figure 6. Summary proficiency data for sonar billets.

Statistical Parameters	Measurement Categories					
	Average Time Between Exercises	Accuracy		Time TMA Convergence (sec)	Proc. Errors (freq)	Comm. Errors (freq)
		TMA MD (mils)	Manual Offsets (yards)			
<u>Posttraining Proficiency</u>						
Quarter Averages	6.2	20.3	120	58	8	10
Past-Quarter Averages	6.0	22.1	115	65	9	13
Long-Term Averages	6.0	21.5	118	62	4	11
<u>Pretraining Proficiency</u>						
Quarter Averages	6.2	38.7	122	95	10	12
Past-Quarter Averages	6.0	37.2	117	102	15	11
Long-Term Averages	6.0	40.1	120	107	10	11

Figure 7. Summary proficiency data for UB plot billets.

The summary printouts provide indices of performance; however, they do not provide diagnostic data that identify specific deficiencies. Although the accuracy and time measures are very exact, the frequency measures for communications and procedures are strictly generalized summaries. For this reason, diagnostic deficiency data printouts containing the information presented in Figures 8 to 11 should be used to augment the summary proficiency data. Specific errors are shown for the sonar and UB plot subteams in communications and operational procedures. A separate printout is provided for each type of error.

Use of Summary Level Data in the PPAS

The PPAS summary level data printouts are intended to provide the Navy personnel manager with an overview of performance proficiency levels and specific types of deficiencies among STG personnel. These printouts are designed to enhance quality control. This is the primary objective of the PPAS. On the Fleet summary data printouts (Figures 6 and 7), the division of scores into pretraining and posttraining groups provides an overview of the proficiency levels maintained by personnel while at sea and the increase in proficiency levels resulting from exercises in the team trainer. This information will help managers identify areas in which performance levels are unsatisfactory.

The presentation of averages for both current and past quarters as well as long-term averages is intended specifically to reflect the actions implemented by various Navy managers in controlling the Navy training process. The comparison of current and long-term averages provides indices of general trends in proficiency in specific areas. However, since the long-term averages are generated for relatively large samples of ships, they are generally not very sensitive to changes in personnel processes. For example, the benefits of improved training methods could not be observed until personnel who have been trained by them reach the Fleet and begin to use the team trainers regularly in large numbers. By comparison, the quarter averages generated from smaller samples of ships may not reflect Fleet levels of performance as accurately but, since they are based on completely updated data, are far more sensitive to the immediate effects of change.

The diagnostic deficiency data printouts (Figures 8 to 11) provide more detailed information on the communications and procedures frequency measures presented in the Fleet summary data. These printouts should enable measures to identify specific errors that are commonly committed across all teams. This information should provide a basis for more informed decisions about changes in ASW team procedures. In general, the suggested data printouts should meet the objectives of the PPAS concept by providing proficiency data that is readily understood by various Navy decision makers.

Ship	Communications Errors															
	Contact/ Lost Contact		Range/ Bearing		Multiple Echoes		No Echoes		Hydro- phone Effects		Approach Baffles		Doppler		Contact Classif- ication	
	omit	late	omit	late	omit	late	omit	late	omit	late	omit	late	omit	late	omit	late
Ship 1																
Ship 2																
Ship 3																
Ship N																
Quarter Totals																
Quarterly Averages Past-Quarter Averages Long-Term Averages																

Figure 8. Diagnostic deficiency data for sonar communications.

Ship	Communications Errors													
	Report TMA Solution		Report Weapon Selection		Report Gyro Search Depth		Request Permission to Fire		Report Standby		Report Weapon Fire Away		Request Director	
	omit	late	omit	late	omit	late	omit	late	omit	late	omit	late	omit	late
Ship 1														
Ship 2														
Ship 3														
Ship N														
Totals														
Quarterly Averages Past-Quarter Averages Long-Term Averages														

Figure 9. Diagnostic deficiency data for UB plot communications.

Ship	Procedural Errors in Control Settings								
	Target Contact/ Lost Contact	Search Track	Mode Select	Sector Center Bearing	Zone Start	Zone Width or Range	XMIT Freq.	Target Tracking Console-Aided Track	Norm/ Narrow Filter
Ship 1									
Ship 2									
Ship 3									
Ship N									
Totals									
Quarterly Averages Past-Quarter Averages Long-Term Averages									

Figure 10. Summary printout of diagnostic deficiency data for sonar procedures.

Ship	Procedural Errors in Control Settings					
	Computer Mode	Speed Analysis Mode	Display Scale	Weapon (Missile or Torpedo) Select	Manual Offsets	Gyro Initial Search Depth Set (MK 268)
Ship 1						
Ship 2						
Ship 3						
Ship N						
Totals						
Quarterly Averages Past-Quarter Averages Long-Term Averages						

Figure 11. Diagnostic deficiency data for UB plot procedures.

DEVELOPMENT OF A DATA COLLECTION SYSTEM FOR THE PPAS

General Requirements for a DCS

An evaluation of the potential performance measures and the ASW team training objectives and requirements has highlighted a number of general requirements for a PPAS Data Collection System (DCS):

1. The DCS must collect data continuously at real-time and store them for reduction after the exercise is completed. These data include vehicle position readings, equipment control settings, and sonar and fire-control cursor positions and cursor errors.

2. The DCS must provide real-time processing or post-exercise batch processing to convert data to usable form (for example, sonar range and bearing error converted to sonar miss distance; TMA course and speed error converted to TMA miss distance).

3. The DCS must include an executive routine that monitors overall trainer processing and controls activation or deactivation of data collection for each performance measure.

4. The DCS must provide a means of collecting and storing data that identifies all STG personnel and their billet stations for each exercise. The system must be capable of relating individuals to the various PPAS performance measures.

5. The DCS must retrieve, reduce, and store data for each individual and each ship. These data must be stored on tape.

6. The taped data must be integrated into a larger PPAS data base that is used for summarization and printout of Fleet summary proficiency/deficiency data and for statistical analyses relating detailed measurement data to appropriate personnel training, selection, and assignment variables.

7. The DCS must collect data from various models of the 14A2 Trainer.

8. The DCS must collect data from the 14A2 Trainer in joint mode with other sonar trainers (for example, 14E19 and 14E23) as well as the independent mode.

These requirements provide a partially automated PPAS DCS. This system would collect and reduce all accuracy and time data as well as personnel data. However, performance measurement data for communication errors and procedural errors would require instructor monitoring, evaluation, and recording. Data checkoff lists could be used for these tasks. The diagnostic deficiency data sheets shown in Figures 8 to 11 are presented as formats for computer-generated printouts; however, checkoff lists with similar formats could be used for manual recording of errors. These forms would show data recorded for each exercise, instead of for each ship. As data collection was completed for each ship, the data would be summarized and transferred to forms identical to those shown in Figures 8 to 11, providing summary data at ship and exercise levels. This process would be laborious and would probably require additional personnel to collect and reduce the data.

Despite the limitations of a partially automated DCS, the evaluation of candidate performance measures clearly demonstrates that such a system is feasible and would be beneficial.

An Automated DCS

If the data obtained in a partially automated DCS demonstrate the overall benefits expected, a more completely automated system might be considered. The more automated system would include the following capabilities:

1. Computer programming to automatically monitor and record all console control settings, evaluate all settings, and record all procedural errors.

2. Development of automated voice-recognition systems to monitor, evaluate, and record all communications errors for STG personnel.

Methods for automatically recording procedural errors could be developed along with methods for collecting accuracy and time data. However, this would entail more extensive programming to monitor control settings, and the development of subroutines to evaluate the control settings. It would also require more extensive modifications to the 14A2 Trainer Complex. The software logic necessary to identify control positions as errors and to evaluate the significance of the errors must still be developed. An analysis of current instructor practices in evaluating procedural errors, appropriate operational systems doctrine, and functional design would provide the baseline for this development.

In the following discussion of methods for implementing a DCS, consideration will be given to the development of techniques for automated recording of procedural errors. However, the development of techniques for the recording of communication errors by automated voice-recognition represents a technological gap in current state-of-the-art capabilities that is not likely to be filled before the initial implementation of a PPAS; consequently, such techniques are not discussed in this report. For a discussion of potential for automatically recording communications errors, see Bell (1978).

Methods of Implementation

A fundamental requirement for automated performance measurement in the 14A2 ASW Team Trainer Complex is that data must be accessible not only from the 14A2 Trainer, but from the sonar trainer that is in joint mode. This is necessary for both sonar and UB plot subteam measurement data. Further, assessment of ASAC (Anti-Submarine Air Controller) and CIC data is required to interpret sonar/UB plot data. Various options for automated performance measurement are feasible. This section will address those options from the viewpoint of providing a DCS fully integrated into the 14A2 complex. The current 14A2 complex configuration provides the basic architectural structure governing the approaches to a performance measurement data collection system, and dictates the hardware and software requirements for implementation of various automated performance measurement options.

A block diagram of the 14A2E complex at FLEASWTRACENPAC is shown in Figure 12. Four sonar trainers are currently integrated into the complex: 14E19, 14E23, 14E24, and 14E27.[4] Each of these trainers interfaces with the 14A2 Tactical Trainer through the Universal Interface Unit (UIU). Transfer of information from the 14A2 to the trainers is via the 14A2E's distributor output table. The 14A2 transfers a 110-word message to the UIU. The message contains environmental data, vehicle position and motion parameters, weapon parameters, and fire control status data. The UIU transfers a 140-word message to all sonar trainers. This message consists of the original 110-word transfer from the 14A2, plus cursor range and bearing position from the sonar trainer selected for joint operation. The transfer occurs at a 1-second rate, and only when a joint mode configuration exists.

Transfer of information from the other trainers to the 14A2 occurs in a similar manner. For example, range and bearing data from the 14E19 are stored in a 96-word distributor output table before being transferred via a direct multiplexer control (DMC) channel to the UIU, where A-scan and B-scan range and bearing are extracted and the data are converted from digital to synchro information to provide fire control and cursor range and bearing inputs for joint mode message reconstruction. Data are transferred from the 14E23, 14E24, and 14E27 Trainers in the same manner but with varying message word lengths and repetition rates.

For clarity, the discussion that follows will focus on the 14E19/14A2 Trainer configuration. Modifications to the 14E23, 14E24 and other sonar trainers would be analogous to those required for the 14E19 Trainer.

The 14A2 Trainer displays all vehicle position and motion data, sonar (SQS-23) and fire control switch positions, and radar and seascope CRTs at the instructors' consoles in the problem control room. The only error data directly displayed are those relating to time for attack. These displays are rarely used. The 14A2 Magnetic Tape Unit (MTU) is capable of recording all vehicle position data; however, no error data are recorded or stored by the computer.

The 14E19 Trainer displays all SQS-26 sonar console switch positions and range, bearing, and doppler error at the 14E19 instructor's console;but its computer, like that of 14A2 Trainer, does not record error data. Nevertheless, all 14E19 Sonar data required for performance measurement including range, bearing, and doppler error, are readily accessible from the 96-word buffer from which data are transferred to the UIU. Similarly, most 14A2 data can be obtained from the UIU 140-word transfer buffer.

The following sections discuss hardware modifications to the 14A2 Complex that would be required to implement various PMS capabilities.

<u>Hardware Modifications</u>

The hardware modifications that would be required to implement automated performance measurement will be addressed at two levels. The first level includes mandatory changes, or changes that would be required irrespective of the options available in implementing automated performance measurement.

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[4]The complex also contains a 14A2A Trainer that is similar to the 14A2E except that the 14A2E has some additional instructor displays and a modified Main Trainer Program.

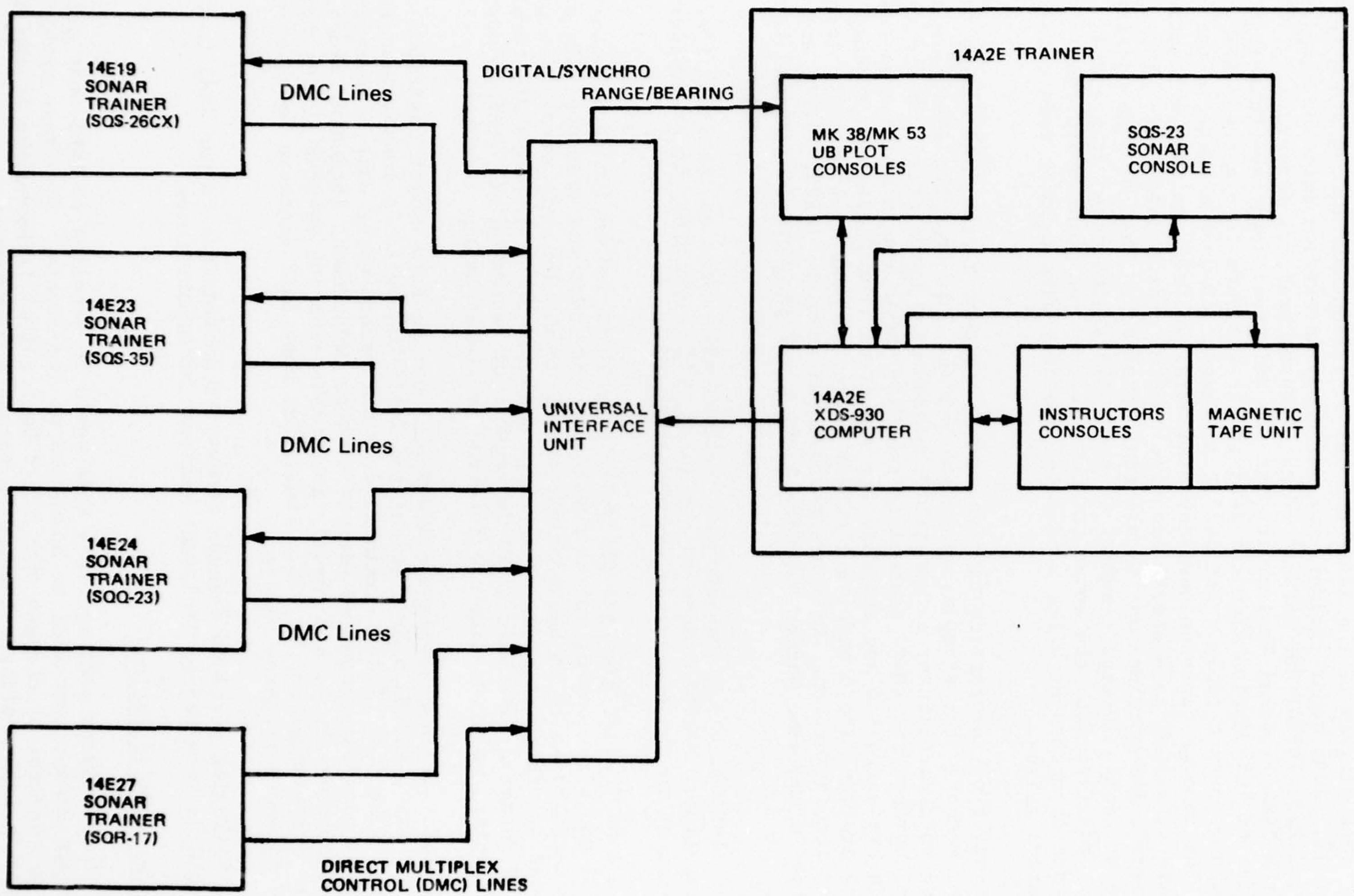

Figure 12. Block diagram of the current 14A2E ASW Team Trainer Complex.

Since the entire 96-word message from the 14E19's distributor output table is transferred to the UIU, it is probable that no further modifications are necessary in the 14E19 Trainer; however, modifications to the UIU would be necessary. UIU logic circuitry must be expanded to extract additional sonar data from the 96-word transfer message, including sonar range, bearing, and doppler error, and all console switch positions. A second modification would be necessary to permit the UIU to communicate with the XDS-930 computer via either the 14A2 general interface, or to provide a separate computer dedicated to automated performance measurement functions. All other modifications are optional.

A fundamental question is where a DCS program should reside. The current 14A2 Main Trainer Program could be expanded to incorporate a parallel, integrated DCS program. The main advantage of this approach is that it would save the cost of a second computer and make data already resident in the 14A2E core readily accessible. However, there are several disadvantages:

1. The 14A2 Main Trainer Program would be extensively affected, and a separate DCS program would be required for the 14A2A trainer (and for each 14A2 model at other sites implementing a DCS, since the main trainer programs differ).

2. The XDS-930 Computer has only 16K words of memory. This is probably insufficient, and expanded memory core size would most likely be required for continuous data storage and to drive optional peripherals.

3. This approach precludes the capability of growth in which performance measurement data could be gathered from two trainers running in independent mode. (This capability is desirable during some advanced training exercises.)

A more likely approach to implementing a DCS is shown in Figure 13. A separate computer dedicated to automated performance measurement would allow considerable flexibility in both system design and growth potential. The following advantages would be gained:

1. Modification to current system hardware would be limited almost exclusively to the UIU. This would limit the effect on the ongoing utilization of the 14A2 including documentation, maintenance, and operational procedures.

2. The 14A2 Trainer could be updated, or replaced, and the new modification or new equipment could be more easily integrated with the established DCS.

3. Partially automated performance measurement data collection could be implemented, with provisions for continued expansion, and such expansion would be independent of 14A2E operations currently being conducted.

4. The DCS system could be easily expanded to permit data collection from both the 14A2E and the 14A2A Trainers.

In order to precisely determine the most cost-effective approach to implementing the type of system shown in Figure 13, it would be necessary to conduct studies that would assess the computer processing capabilities and memory size necessary to store the software required to compile all appropriate performance measurement data and to provide input/output control of the peripherals that would be incorporated into the DCS.

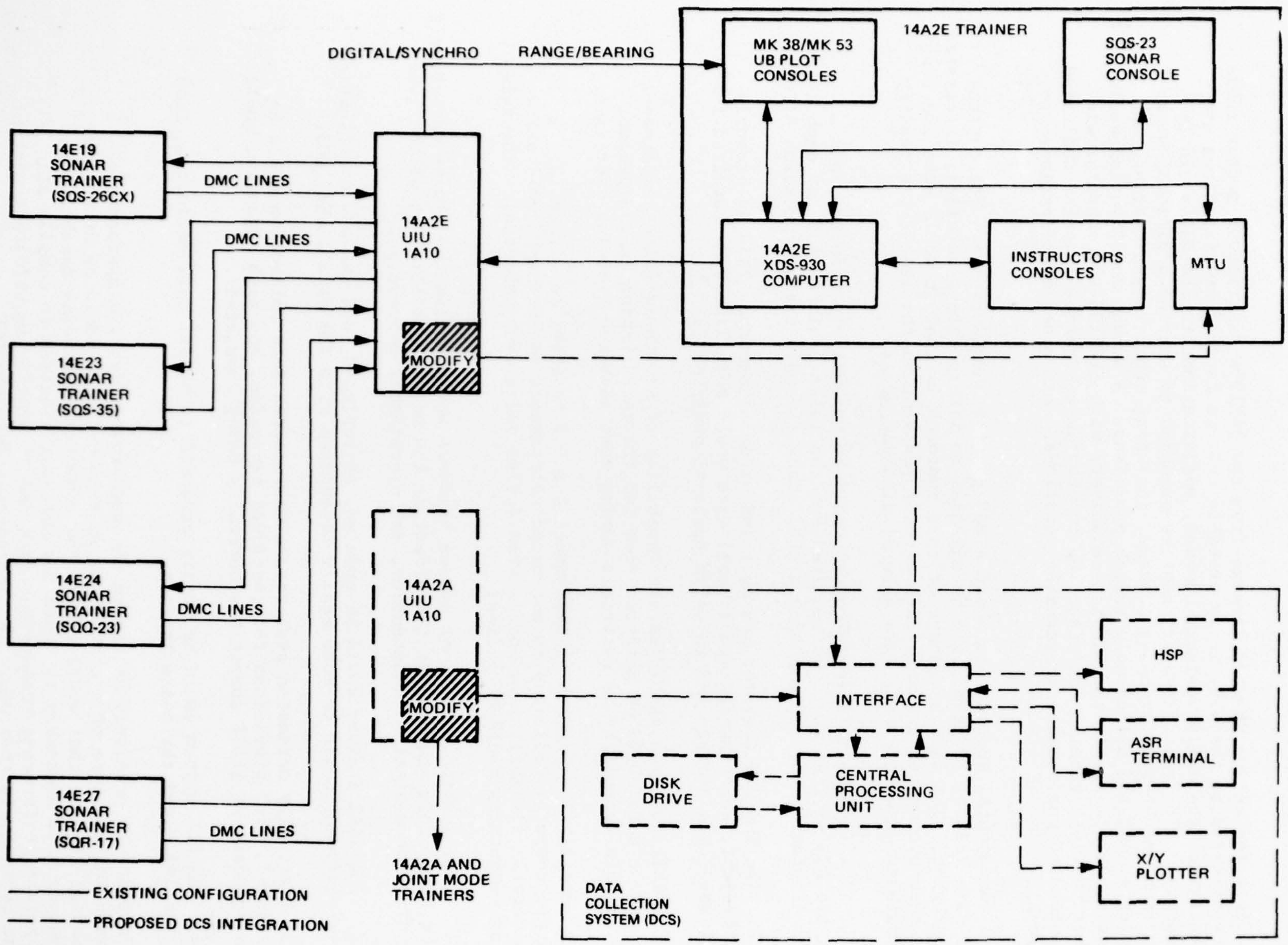

Figure 13. Proposed integration of PPAS DCS with 14A2 Complex.

A corollary issue is the possible use of a disk device to store data instead of using computer memory. In order to collect continuous data such as sonar and TMA error data, it is probable that a disk would be necessary. The disk is a mass storage device that can be used in either of two ways. First, it can be used to store raw data that could later be accessed by the CPU for appropriate reduction, formatting, and output to peripherals. Second, it can be used to store already formatted data for subsequent output. The method adopted would probably depend upon how rapidly data are received from the interface.

The only required peripheral devices, other than a disk drive, are (1) an automatic send/receive (ASR) teletype terminal or an alphanumeric keyboard/CRT, and (2) a high speed printer (HSP). Optional peripherals include (1) a magnetic tape unit (MTU), and (2) an X/Y plotter. Each of these peripherals provides unique advantages for data input/output and enhanced performance measurement capability.

The ASR terminal would serve as the basic input/output device. An ASR terminal can be used to print summary statistics data; however, this would provide slow, relatively inefficient, and limited printout capability. If a keyboard/CRT terminal were to be used, the data would have to be printed by HSP. The terminal would be used for several purposes:

1. To enter personnel social security numbers and assigned billet stations for each exercise.

2. To enter a system configuration mode instruction word. This instruction word would tell the DCS computer which trainers are being used (for example, 14A2A independent, or 14A2E and 14E19 in joint mode) and thereby define for the system the data that are to be accessed and stored.

3. To control other peripherals, such as the HSP, by specifying the desired data to be printed out.

4. To run DCS utility programs for maintenance of the system.

The HSP is required for efficient data printout. Although data could be printed on an ASR terminal, the HSP would allow much faster printout and provide greater flexibility in format. Since PPAS data will probably have to be recorded on tape and be integrated into a central data base, an HSP could be provided for the central data base computer. This would make it unnecessary to provide an HSP at each training center.

PPAS data would be stored permanently on tape through the magnetic tape unit (MTU). It might be possible to use one of the trainer's MTUs to store data, as is shown in Figure 13. This could be accomplished only if the MTU is compatible with the PPAS computer and with the MTU of the central PPAS data base. Otherwise, each training center would be required to have an MTU dedicated to the PPAS.

The X/Y plotter would provide a means for printing out graphs of error data.

Software Modifications

The temporary data collection programs and data reduction programs developed for this research demonstrate the feasibility of developing software for a permanent performance measurement data collection system. Currently, there is no programming provided in the main trainer programs of the 14A2E (or 14A2A) to collect, store, reduce, or print performance measurement data. The limitations of the temporary data collection programs can be overcome, and programs could be developed to obtain valuable performance measurement data. If an approach to integrating a PPAS DCS similar to that illustrated in Figure 13 is taken, a comprehensive computer program must be developed. The overall program structure would be dependent on the design of hardware modifications, and specifics cannot be delineated at this time. However, an analysis of the various performance measures to be obtained and the uses to which they will be put dictates the following functional requirements for the computer program:

1. Monitor and record all control positions for the appropriate sonar and UB plot consoles, and record times at which changes occur.

2. Provide subroutines to evaluate control position status and changes based on current tactical conditions or related system configurations.

3. Record range, bearing, and doppler error at each NDT time, and store these data for reduction and scoring after the exercise is completed.

4. Record TMA course and speed error during the appropriate time intervals.

5. Store TMA error data for reduction and scoring after the exercise is completed.

6. Monitor and record total contact time.

7. Record all fire control status data.

8. Provide a general executive routine controlling all data access, transfer, and processing.

9. Control and drive data storage and retrieval on a disk device.

10. Control peripherals for printouts of all required performance measurement data.

CONCLUSIONS

1. Data from the 14A2 ASW Team Trainer Complex can provide useful inputs to a Performance Proficiency Assessment System.

2. Procedures can be developed for summarizing and presenting proficiency/deficiency data so that these data can be readily understood by Navy personnel managers.

3. Procedures can be developed for automating the collection and analysis of the desired information.

FUTURE ACTIONS

On the basis of the information provided in this report, NAVPERSRANDCEN will take these actions:

1. Experiments will be carried out to determine the degree to which the types of performance information described in this report would be useful as part of a Performance Proficiency Assessment System. The performance data recommended in this report will be gathered from a sample of approximately 100 ASW teams, summarized in a manner similar to that shown in Figures 3 to 11, and presented, along with any additional data that may be required, to appropriate decision makers. For these experiments, the desired data will be gathered using refined versions of the procedures followed to gather data for this report.

2. If it is determined that such information is useful, the steps will be identified that must be taken to automate the collection and analysis of performance data from the 14A2 ASW Team Trainer Complex. The automation would be based upon the procedures and techniques outlined in this report.

REFERENCES

Bell, J. D. Report on performance measurement in ASW, team training (NPRDC Tech. Rep.). San Diego: Navy Personnel Research and Development Center, 1979. (In press)

Dixon, W. J., & Massey F. J. Introduction to statistical analysis (2nd Ed.), New York: McGraw-Hill Book Co., 1957.

Pickering, E. J., & Anderson, A. V. Measurement of job performance capabilities (NPRDC Tech. Rep. 77-6). San Diego: Navy Personnel Research and Development Center, December 1976.

Pickering, E. J., & Anderson, A. V. Measurement of the shipboard performance capabilities of Navy enlisted personnel. Productivity enhancement: Personnel performance assessment in Navy systems. Proceedings of the Symposium held at the Navy Personnel Research and Development Center, San Diego, California, 12-14 October 1977.

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Commanding Officer, Naval Development and Training Center (Code 0120)
Commanding Officer, Naval Education and Training Support Center, Pacific (Code N1B)
Commanding Officer, Naval Training Equipment Center (Technical Library)
Officer in Charge, Naval Instructional Program Development Detachment, Great Lakes
Officer in Charge, Naval Education and Training Information Systems Activity, Memphis Detachment
Director, Training Analysis and Evaluation Group (TAEG)
CNET Liaison Office, Air Force Human Resources Laboratory, Williams Air Force Base
Defense Documentation Center (12)